8.—The largest known dumbbell-shaped australite

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Manuscript received 18 May 1965; accepted 22 June 1965.

Abstract

The largest known dumbbell-shaped australite, discovered in 1960 near Cuballing in Western Australia, is the longest, and the fourth heaviest, australite recorded. It is 100 mm long, weighs approximately 176 grams, and is further evidence than most of the larger and heavier australites occur in the western parts of the Australian tektite strewnfield. The sculpture pattern of the specimen is dominated by pits and grooves resulting from natural solution etching in a terrestrial environment. There are no clearly recognizable remnants of the outer aerodynamically heated skin that is developed on australites during their hypersonic passage earthwards through the atmosphere.

Introduction

A large australite of somewhat irregular dumbbell shape has been kindly lent by J. H. Lord, Director of the Geological Survey of Western Australia, for purposes of description. The specimen was brought to notice by Mr D. Jackson, whose father discovered it in 1960 on a property near Cuballing, north of Narrogin, Western Australia. Cast replicas are lodged in the collections of the Western Australian Museum (12323) and the Geological Survey of Western Australia (R2024). Cuballing (117°5'E; 32°51'26"S) is approximately 96 miles southeast of Perth. The specimen was found at the surface on a ridge in a paddock which had been ploughed.

Its shape is nearest to that of the more regularly dumbbell-shaped australites. Although the waist region is not as marked as in most other australite dumbbells, it is nevertheless distinct to the eye and to the touch, and the two gibbosities on either end of the waist region are of somewhat different dimensions (Fig. 1).

Size of the specimen and the relationship of its size and weight to that of other large australites

The specimen is 100 mm long. Its width ranges from 42.0 mm across the larger gibbosity to 35.8 mm across the smaller gibbosity, the depth (= thickness) measurements for which are 33.7 mm and 25 mm respectively. Its weight of nearly 176 grams makes this dumbbell-shaped form the fourth heaviest of the known large australites.

Thirteen australites that each weigh over 100 grams (Fenner 1955; Baker 1961, 1962, 1963) are at present known. Of these, only three weigh over 200 grams: from Warralakin, W.A., Lake Yealering, W.A., and Karoonda, S.A. The elongated australite from Cuballing, W.A., now replaces the round australite core from Graball, W.A. (Baker 1963) as the fourth heaviest australite known (see Table 1). The total weight of the thirteen specimens is approximately 1,972 grams.

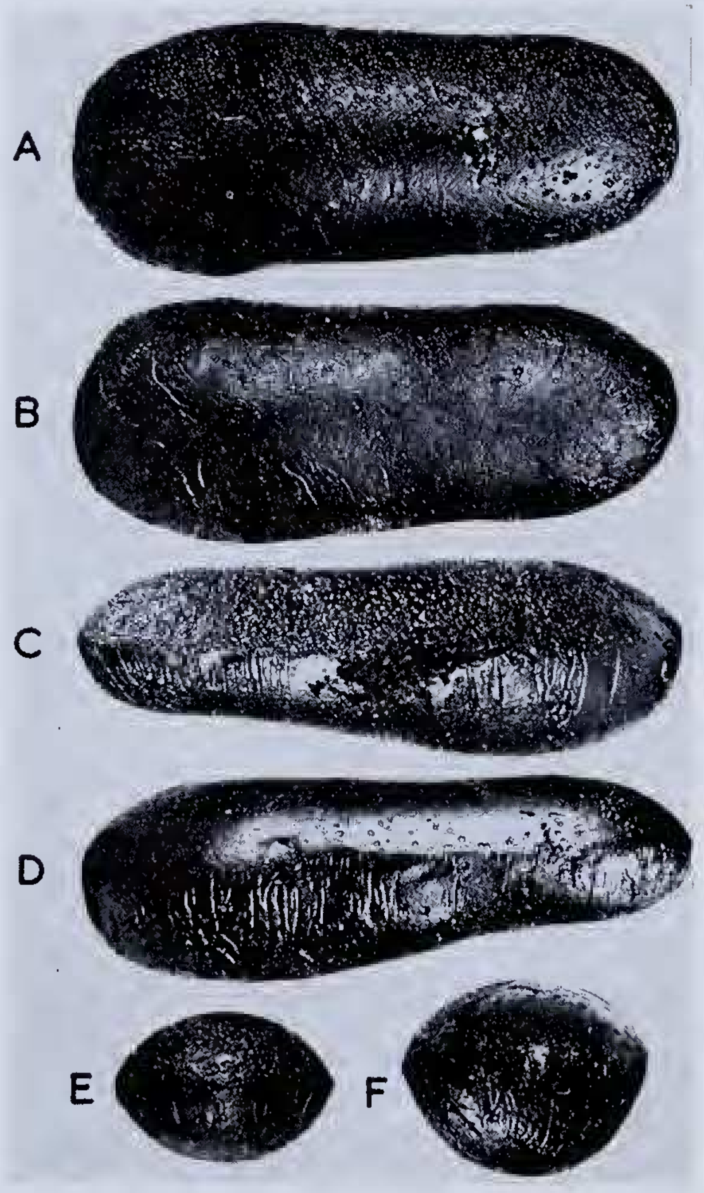

Figure 1.—Largest known dumbbell-shaped australite, Cuballing, Western Australia. A.—Posterior surface showing fine flow lines and surficial pits of variable distribution density. B.—Anterior surface showing gutters and surficial pits; the pits tend to be fewer but somewhat larger generally than on the posterior surface. C.—Side aspect (posterior surface uppermost) showing rim delineating posterior and anterior surfaces; maximum etching has occurred in the region of the rim (darker regions in centre of photograph). D.—Opposite side aspect (posterior surface uppermost) to that in C. Fewer pits are revealed on the posterior surface compared with C; gutters in the equatorial regions of the anterior surface are equally as marked as in C. E.—End-on aspect of smaller gibbosity, showing pits on posterior surface and gutters on anterior surface. F.—End-on aspect of larger gibbosity, showing fewer pits on right-hand side of posterior surface and well developed gutters on anterior surface. For dimensions see text. (Photographs by R. K. Blair.)

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As received, hand lens inspection of the Cuballing specimen revealed that about two dozen of the surficial pits contained soil constituents partially cemented on to the pit walls. Before weighing the specimen in air and in deionized water for specific gravity determinations, these adventitious constituents were largely removed by immersing the specimen in 1:1 HCl in a beaker placed in an ultrasonic vibrator. One effect of the removal of the soil constituents was to reveal the rather high degree of lustre of the pit walls compared with the surrounding glass of the tektite surface.

Table 1 shows that the dumbbell-shaped australite from Cuballing is the longest form (100 mm) on record among the heaviest australites. Furthermore, there are no elongated specimens of more slender character weighing under 100 grams that measure anywhere near 100 mm.

Although the Cuballing specimen is 18 mm longer than the heaviest known elongated australite (from Karoonda, S.A.; see No. 3, Table 1) it is significantly narrower (by nearly 5 mm as a minimum) and thinner (by approximately 4 mm as a minimum), and is hence lighter in weight by almost 33 grams.

TABLE 1

Dimensions and weights of the known australites weighing over 100 grams

No.	Shape type	Locality of discovery	Size measurements* (mm.)	Weight (gms.)	Specific gravity	Reference
1	Oval core	Warralakin, W.A.....	70 (65) x 62·5 x 42	238 (approximately 265 gms. allowing for piece artificially spalled off)	2·409	Baker, 1962 (Plate I, Figs. A to D).
2	Round core	Lake Yealering, W.A.	64 x 64·5 x 39·4	218	....	Fenner, 1955 (Plate VII, nos. 1 & 2)
3	Boat (abraded)	Karoonda, S.A.	82 x 46·8 x 37·9	208·9	....	Fenner, 1955 (Plate VII, nos. 3 & 4)
4	Dumbbell	Cuballing, W.A.	100 x 42 (35·8) x 33·7 (25)	175·996	2·435 (T_{H_2O} = 23·1° C)	(this paper)
5	Round core	Graball, W.A.	57 x 34·5	168·28	2·434	Baker, 1963 (Plate I, Figs. A & B)
6	Oval core (chipped)	Western Australian Goldfields	51·5 x 48·5 x 43	154·3	....	Fenner, 1955 (Plate VII, nos. 5 and 6)
7	(not given)	Corrigin, W.A.	(not given)	147	....	Fenner, 1955 (not illustrated)
8	(not given)	Lake Buchanan, W.A.	(not given)	116	....	Fenner, 1955 (not illustrated)
9	Round core (slightly oval from weathering)	Between Karoonda and Lowalda, S.A.	52·1 x 51·5 x36·5	113	....	Fenner, 1955 (Plate VII, nos. 7 & 8)
10	Broad oval	Babakin, 170 miles E. of Perth, W.A.	52 x 46 x 37·5	112·9	....	Fenner, 1955 (not illustrated)
11	Round core (slightly oval from weathering)	Norseman, W.A.	51·1 x 50·5 x 33·1	111	....	Fenner, 1955 (Plate VIII, no. 14)
12	Boat	Narembeen, W.A.....	64 x 37 x 30·5	107·457	2·431	Baker, 1961 (Plate I, Figs. A to E)
13	Oval core	Karoni, W.A.	49·1 x 45·5 x 35·5	101	....	Fenner, 1955 (Plate VIII, nos. 15 & 16)

* The size measurements are given in the order: length, width, depth (= thickness), for the elongated examples; and in the order: diameter, depth, for forms that are round in plan aspect. Numbers given in brackets are the lowest values for ranges in width and depth for specimens (such as the Cuballing example) having maximum and minimum width and depth values arising from departures from the more regular shape types.

It is notable that of the thirteen largest and heaviest australites placed on record (Table 1), 85 per cent have been discovered in Western Australia at the western end of the 2,000-mile long tektite strewnfield, 15 per cent come from the south-central portion of the island continent, while none weighing over 100 grams are yet known from the eastern States of Australia.

Arcs and radii of curvature of the surfaces

In planes normal to the long axis of the specimen and through the thickest portions of the larger and smaller gibbosities, silhouette traces of the curved posterior surface (top surface in Fig. 1 C-F) and anterior surface (bottom surface in Fig. 1 C-F) were found to fit closely the arcs of curvature of circles constructed about these surfaces. For these surfaces, the radii of curvature (R_B and R_F) were determined graphically with the results shown in Table 2.

TABLE 2

Radii of the arcs of curvature across the width of posterior and anterior surfaces for the larger and smaller gibbosities respectively

	Larger gibbosity	Smaller gibbosity
R_B (mm.)	23·0	20·0
R_F (mm.)	20·0	20·0

R_B = radius of curvature of posterior (back) surface.
R_F = radius of curvature of anterior (front) surface.

From Table 2 it is seen that whereas the original radius of curvature of each gibbosity, as given by the R_B values, differed by 3 mm, the ultimate radius of curvature of the anterior surface, as given by the R_F values, become the same. This was evidently largely a consequence of aerodynamic ablation of the surface facing down the flight path during hypersonic transit through the earth's atmosphere, rather than a result of subsequent spallation and natural solution while resting on the earth's surface.

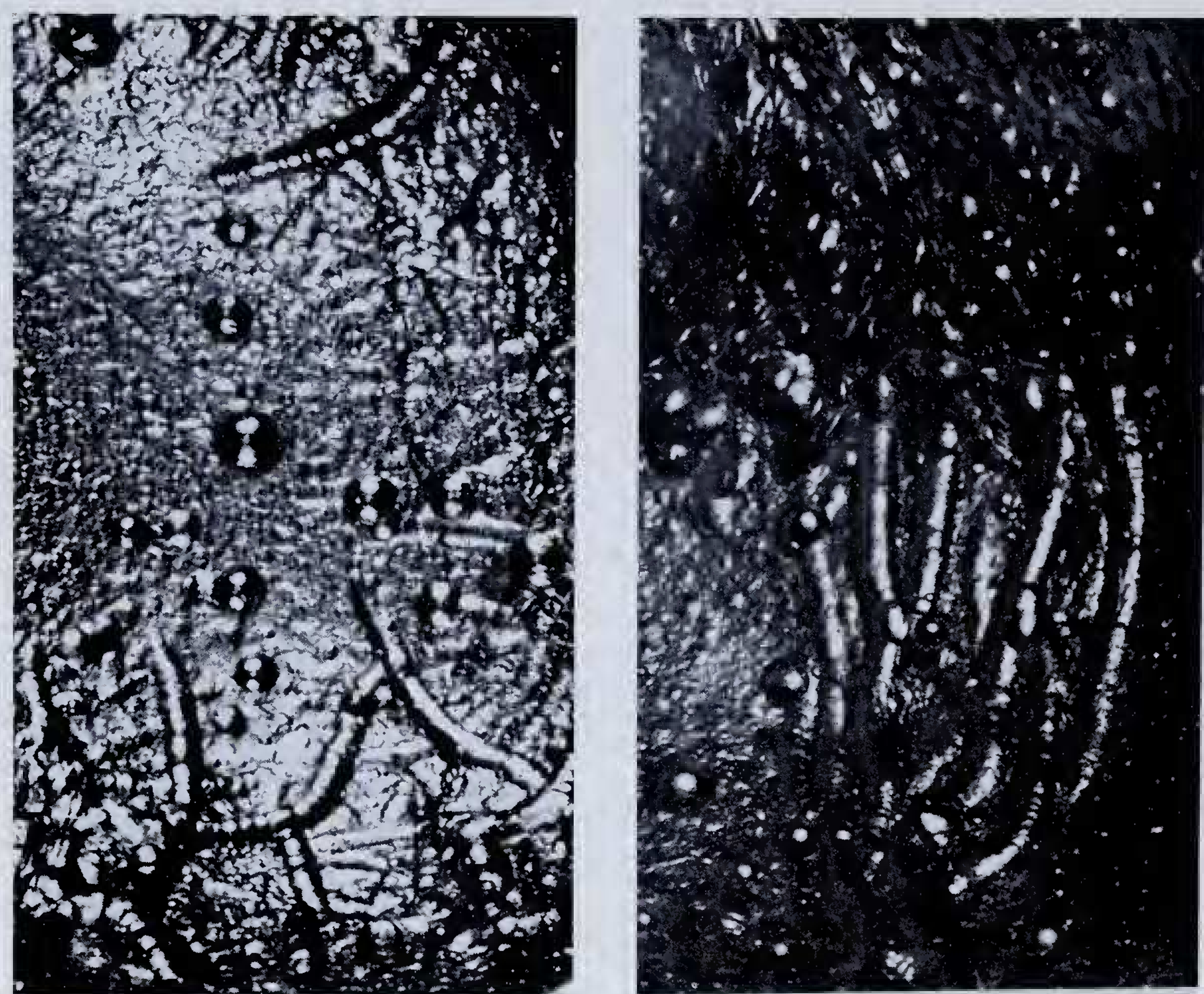
Sculpture of the surfaces

The two surfaces, posterior and anterior respectively, reveal contrasted sculpture patterns. The posterior surface (Fig.1A) is pitted in parts and elsewhere shows smoother, flow-lined patches. The anterior surface (Fig.1B) shows much less pitting and more marked grooving by narrow gutters. These features are fundamentally a result of differential natural solution etching during the several thousand years that the specimen has lain in a soil environment.

The pits range from 0.5 mm to 2.0 mm across and are circular (Fig.3 A&B) to sub-circular and less commonly oval (Fig.2) in outline; many of them are hemispherical. The gutters range from 0.5 mm to 1.5 mm wide, are straight to meandrine in trend (Fig.1 B-F; Fig.2; Fig.3 A&B) and are largely confined to the anterior surface, being more marked in the equatorial regions (Fig.1 B, C&D). These gutters principally trend at right angles to the relatively sharply defined rim separating the posterior and anterior surfaces (Fig.1 C&D; Fig.2), commencing at the rim, traversing the equatorial zone of the anterior surface, and curving and dying out in the less etched regions of the anterior surface (Fig. 1B).

Presumably for much of the time that the specimen has lain embedded in soil, its posterior surface faced downwards, evidently with a slight tilt in view of the more pitted character of one side (top of Fig.1A, and middle of C) relative to the other (bottom of Fig. 1A). In this position of rest, natural etchants carried in soil solutions moving downwards over the

Figure 2.—Sculpture of largest known dumbbell-shaped australite, Cuballing, Western Australia. x3.45 Enlarged end-on aspect of larger gibbosity, showing pits and gutters. Some of the gutters intersect at different levels, some are oblique to the flow line trends of the tektite glass. (Photograph by R. K. Blair).



A B

Figure 3.—Sculpture of largest known dumbbell-shaped australite, Cuballing, Western Australia. x4.7. Enlargement showing randomly developed gutters of different depths, and circular pits, on the anterior surface of the smaller gibbosity (cf. right-hand end of fig. 1, B); note that some of the gutters have a segmented appearance. B.—Enlargement showing sub-parallel gutters some of which inerconnect on the equatorial portion of the anterior surface of the larger gibbosity (cf. lower right-hand end of Fig. 1C); the pitted posterior surface is represented by the upper portion of the photograph. Micro-pits can be observed on the floors and walls of some of the gutters. (Photographs by R. K. Blair).

curved upwardly directed anterior surface acted differentially in equatorial regions to form the gutters.

A feature of the etched-out gutters (and this also applies to some of the pits) is their variability in depth. The gutters shown in Figures 1 and 2 occasionally come into contact with each other at the same level, but sometimes at a different level, some being up to twice as deep as others. The gutters are U-shaped in cross-sectional aspect, so that where shallower gutters meet deeper gutters at an angle the appearance of miniature "hanging valleys" is produced. Such a feature does not seem consistent with an origin by aerodynamic ablational sculpture. Furthermore, the walls and floors of the U-shaped gutters mostly reveal micro-etch pits from place to place. These have resulted (Fig.3B) from local overdeepening, more likely by the process of natural solution etching.

Some of the gutters have a segmented "vermicular" appearance (Fig.3A) where the low walls of adjacent etch pits meet in ridges trending normal to the lengths of the gutters. In other gutters, striae representing part of the sub-surface schlieren pattern of the tektite glass, made evident by differential solution etching, sometimes trend normal to, less frequently almost parallel with, the trends of the gutter walls. These again are not the type of features to be expected from the effects of aerodynamic sculpture, and the striae more likely become evident as a consequence of the etching out by soil solutions of adjacent streaks of glass of slightly different chemical composition.

The walls and floors of several of the pits also reveal the striae and occasionally also possess smaller etch pits, while some pits are twice as deep as other pits of comparable diameter; this evidently partially results from overdeepening along bundles of schlieren lying approximately normal to the tektite surface. Less etched portions of the anterior surface (Fig.3A) show a pattern like the surface of an orange.

On parts of the posterior surface, the etch pattern follows the trend of the internal schlieren, thus exposing the complex pattern of flow streaks, visible on the bottom half of Figure 1, A, as fine lines.

Solution etch gutters on the posterior surface are fewer, shorter and shallower, compared with the gutters on the anterior surface.

The conclusion is that the sculptural features such as the gutters and many, if not all, of the pits on the anterior and posterior surfaces of the dumbbell-shaped australite from Cuballing, are tertiary features arising from natural, terrestrial, solution-etching, and that they are not due directly to the secondary process of an aerodynamic ablational sculpturing during hypersonic transit through the earth's atmosphere. In substantiation of this conclusion, it is noteworthy that there was no evidence of the formation of gutters on the front surfaces of tektite glass test models during an experimental programme recently conducted by the Space Sciences Laboratory of the General Electric Company, Pennsylvania, U.S.A. This programme was instituted to investigate various criteria suggested for the formation of surface irregularities on tektite bodies, and it was thought there might be a likelihood of the formation of surface grooving by a possible Gortler-type boundary layer instability. Using a relatively narrow range of test environments in the Hypersonic Arc Tunnel (Diaconis and Johnson 1964) no surface grooves resulted.

Features observed under the microscope

A small area of the posterior surface has been chipped, and reveals that a little of the tektite glass has been lost by minute fracture spallation. This evidently occurred subsequently to the discovery of the specimen. The area is towards the right-hand end of Figure 1, A. Examination of this area under a binocular microscope reveals the highly vitreous lustre of the freshly exposed tektite glass and also its conchoidal fracture pattern. The larger of the fracture surface areas, which measures 6 mm by 3 mm in area and is lunate in outline, also reveals secondary ripple fracture.

A thin sliver of the glass was mounted in Lakeside cement for examination of its internal structure under a petrological microscope. The thin sliver resulted from breaking the walls of a pit approximately 0.5 mm across when attempting to free it of relatively firmly lodged adventitious clay constituents. Under crossed nicols of the petrological microscope, the glass revealed almost complete isotropism with no significant strain birefringence. Only very rarely is birefringence weakly shown as a narrow, indefinite, partial zone around one or two of the lechatelierite particles (also isotropic) embedded in the glass. The shapes and sizes of the more readily distinguishable lechatelierite particles are listed in Table 3.

TABLE 3

Shapes and sizes of lechatelierite particles embedded in a small sliver of tektite glass detached from the dumbbell-shaped australite from Cuballing, Western Australia

	Shape	Size (μ)
a	irregular, rod-like	100 x 25
b	sub-spherical	40
c	rod-like	30 x 5
d	roughly triangular	10
e	ellipsoidal with hooked ends	60 x 25

From the Becke line test, it was determined that the lechatelierite particles have a refractive index somewhat below that of the neighbouring isotropic tektite glass, while the glass itself has a much lower index of refraction than that of the mounting medium (Lakeside cement).

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